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Revolutionising Critical Care With AI

The Measure of AI: An ABCDEF Framework for Critical Care Clinicians, *B Murray, A Tilley, EF Barreto, SR Bauer, SE Smith, Y Gao, N McCourt, T Liu, A Sikora*

Risk Prediction of ICU Admission and Artificial Intelligence: A Narrative Review, *R Losiggio, FM Oliva, D Pontillo, S Turi*

From Concept to Code: AI-Powered CODE-ICH Transforming Acute Neurocritical Response for Haemorrhagic Strokes, *S Salman, R Corro, DK Sanghavi, C Kramer, S English, PM Franco, T Menser, K Thielen, WD Freeman*

Artificial Intelligence: A Revolution in Critical Care...But? Navigating Opportunities and Challenges in the Age of AI, *A Naharro-Abellán, F Gordo*

Echocardiography and Cardiac Output Monitoring: Towards Techquity, *F Michard, A Wong*

How Computer Vision Can Change the Future of Medicine: From Missed Observations to Continuous Insight, *HL Lindroth, BW Pickering, V Herasevich*

Humanising the Escalation of Care: Developing COURAGE as a Tool for Patient Safety, *F Tabbara, L Hawryluck*

The Journey from ANDROMEDA-SHOCK 1 to ANDROMEDA-SHOCK 2: How Capillary Refill Time Became a Driver of Personalised Haemodynamic Management , *OR Pérez-Nieto, G Hernández-Poblete, E Kattan, G Ospina-Tascón, G Ferri-Sánchez, E Deloya-Tomas*

Volume Responsiveness in the Obese Patient: An Unresolved Challenge, *D Escarramán Martínez, MA Guerrero Gutierrez, GA Solís Pérez, JM Antolinez-Motta, GD Martínez Sedas, M Minutti Palacios*

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Volume Responsiveness in the Obese Patient: An Unresolved Challenge

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Dynamic indices have been introduced as a complementary tool for haemodynamic monitoring, leveraging cardiopulmonary interactions to assess fluid responsiveness in mechanically ventilated patients. In patients with obesity, fluid management poses an even greater challenge due to marked cardiovascular and pulmonary alterations that can compromise the accuracy and reliability of these indices. Consequently, their interpretation requires careful clinical judgement and contextualisation.

Introduction

Dynamic haemodynamic monitoring has transformed our understanding of fluid management in both the perioperative setting and critically ill patients. Currently, there is strong evidence supporting the negative clinical impact of fluid overload, which is associated with increased morbidity and mortality. In this context, indices such as stroke volume variation (SVV), pulse pressure variation (PPV), and the plethysmographic variability index (PVi) have emerged as valuable tools for identifying clinical scenarios in which fluid administration may represent the most appropriate haemodynamic rescue strategy, helping to avoid volume overload and its associated adverse outcomes (Elia et al. 2023).

This type of monitoring is based on the cyclic fluctuations in blood flow that occur throughout the respiratory cycle (inspiration and expiration), known as cardiopulmonary interactions. However, for dynamic indices, SVV, dPV, and PVi, to be considered reliable and clinically useful, several physiological conditions must be met. Among the most important are controlled positive pressure ventilation with a tidal volume of 8 mL/kg of predicted body weight, sinus rhythm, adequate neuromuscular blockade (absence of spontaneous breathing), preserved thoracopulmonary compliance, normal systolic and diastolic cardiac function, and the absence of significant pulmonary hypertension (Monnet et al. 2018). Failure to meet these conditions may compromise the validity of dynamic indices, leading to misinterpretation and potentially inappropriate clinical interventions.

Patients with obesity exhibit significant cardiopulmonary alterations that may compromise the accurate interpretation of dynamic indices. Pulmonary compliance is reduced due to increased intra-abdominal pressure, cephalad displacement of diaphragm, and elevated chest wall elastance. At the cardiac level, increased circulating blood volume may lead to left ventricular hypertrophy with potential diastolic dysfunction, as well as an elevated risk of pulmonary hypertension and right ventricular dysfunction. In addition, elevated intra-abdominal pressure can impair venous return by increasing resistance to venous flow (Busebee et al. 2023). These physiological changes alter ventilatory mechanics and cardiopulmonary interactions, thereby affecting the performance of dynamic indices such as SVV, dPV, and PVi.

Cardiopulmonary Interactions

Dynamic indices are based on cardiopulmonary interactions resulting from the cyclic changes that occur during positive pressure mechanical ventilation (MV). During the inspiratory phase, the increase

in intrathoracic pressure is transmitted to the right atrium, generating a pressure gradient relative to the vena cava that reduces venous return to the right ventricle, leading to a transient decrease in its stroke volume (Hamahata et al. 2023). Simultaneously, the elevated intrathoracic pressure decreases left ventricular afterload, facilitating its ejection and resulting in a transient increase in left ventricular stroke volume. This occurs due to a reduction in transmural pressure and a leftward displacement of the interventricular septum, which favours left ventricular emptying. In addition, the rise in alveolar pressure during inspiration compresses the alveolar capillaries, increasing pulmonary vascular resistance and right ventricular afterload, further exacerbating the decrease in right ventricular stroke volume. During expiration, intrathoracic and alveolar pressures decrease, allowing recovery of venous return to the right ventricle and a reduction in pulmonary vascular resistance, thereby contributing to the cyclic restoration of biventricular stroke volumes (Berger et al. 2023).

The pathophysiological changes associated with obesity significantly impact cardiopulmonary interactions. The increase in abdominal mass and thoracic fat elevates intra-abdominal pressure, which is transmitted to the thoracic cavity, resulting in a decreased venous return gradient (systemic filling pressure minus right atrial pressure), thereby compromising venous flow to the heart. The reduced compliance of the chest wall and pulmonary parenchyma leads to a non-linear relationship between tidal volume and intrathoracic pressure changes induced by mechanical ventilation. Additionally, right ventricular dysfunction renders the right heart more susceptible to afterload variations generated during mechanical ventilation, which in turn alters the cyclic stroke volume response (Hamahata et al. 2023; Berger et al. 2023). In summary, pressure transmission is no longer physiological, chronic impairment of venous return is present, and the right ventricle may not respond in the same manner as in a normoweight patient. **Table 1** summarises the specific impact on dynamic indices.

Clinical Evidence

Evidence in this context remains limited. In a prospective cohort of 50 patients with morbid obesity undergoing laparoscopic bariatric surgery, Jain et al. (2010) used SVV to guide intraoperative fluid therapy, employing a cutoff value of 10%. The study suggested that SVV-guided optimisation may be critical to avoid fluid overload in this population, given that their fluid requirements do not significantly differ from those of normoweight patients, despite notable physiological alterations. In a separate observational study, DeBarros et al. (2015) evaluated the reliability of the PVi during abdominal procedures. Patients were stratified by surgical approach (open vs laparoscopic) and body mass index (BMI: obese vs. non-obese), totalling 63 participants. They observed that abdominal insufflation increased baseline PVi values during laparoscopic procedures, particularly in obese patients, leading to falsely elevated readings. This finding may compromise the clinical utility of PVi as a fluid responsiveness indicator in this setting. More recently, a prospective cohort study (Demirel et al. 2018) assessed goal-directed fluid therapy using PVi compared to conventional central venous pressure (CVP)-based management in 60 patients with morbid obesity undergoing laparoscopic Roux-en-Y gastric bypass. The PVi-guided group received significantly less crystalloid volume (1126mL vs 1499mL, p=0.001) without compromising tissue perfusion or renal function. This supports

Obesity-related alteration	Effect on dynamic indices	Clinical consequence
↑ Intra-abdominal pressure ↑ Intrathoracic pressure	Reduced venous return gradient	↓ Sensitivity of dPV/SVV to predict fluid responsiveness
↓ Chest wall and pulmonary compliance	Non-linear transmission of tidal volume into intrathoracic pressure changes	False-negative dPV/SVV values
Presence of auto-PEEP and alveolar collapse	Impaired venous return during expiration	Distorted dPV/SVV patterns
Right ventricular dysfunction	Abnormal RV response to changes in afterload	False-positive or false-negative indices
Regional ventilation heterogeneity (atelectasis)	Uneven pressure transmission across lung regions	Erratic variability in dynamic indices

Table 1. Specific impact on dynamic indices. dPV: pulse pressure variation; VVS: stroke volume variation; PEEP: Positive End-Expiratory Pressure; RV: right ventricular

the feasibility of individualised strategies based on dynamic indices to minimise fluid overload in this population. Complementing this evidence, a prospective cohort study (Ali and Dorman 2019) validated the use of a 100mL mini-fluid challenge as an effective tool to predict fluid responsiveness in patients with BMI ≥30kg/m² positioned prone. The test demonstrated a positive predictive value (PPV) of 100% and a negative predictive value (NPV) of 90%, outperforming dPV (PPV 58%, NPV 88%) and SVV (PPV 59%, NPV 82%). This approach may be particularly useful in scenarios where traditional dynamic indices lose accuracy, such as in obese patients or during non-standard surgical positioning.

In a secondary analysis of a prospective cohort of 60 patients (Flick et al. 2021) with 337 paired measurements taken every 15 minutes, noninvasive measurement of dPV using ClearSight® technology (dPPfinger) was compared with invasive dPV measurement via an arterial line using the FloTrac® monitor (dPPart). Agreement between the two methods was evaluated across three dPV categories (<9%, 9–13%, >13%) using both the rate of concordant paired measurements and Cohen's kappa coefficient. Overall predictive concordance was 72.4%, with a Cohen's kappa of 0.53. Notably, dPPfinger tended to overestimate dPPart values when dPV exceeded 13%. These findings suggest that whilst noninvasive monitoring may serve as a useful tool, its interpretation should be approached with caution in obese patients undergoing laparoscopic surgery, particularly in scenarios requiring high precision for critical haemodynamic decisions. Importantly, unlike prior studies that primarily focused on methodological validation, inter-device agreement, or diagnostic performance of dynamic indices (Jain et al. 2010; DeBarros et al. 2015; Demirel et al. 2018; Ali et al. 2019; Flick et al. 2021), a prospective cohort study of 210 patients with morbid obesity undergoing laparoscopic sleeve gastrectomy (Urhan et al. 2024) represents a clinically applied investigation. It directly assessed the impact of different goal-directed fluid therapy strategies on relevant clinical outcomes. By comparing three dynamic monitoring approaches, systolic pressure variation (SPV), dPV, and PVi, the authors evaluated tissue perfusion markers, renal function, and length of hospital stay. Although differences were observed in the amount of colloid administered, there were no significant differences in clinical outcomes, suggesting that none of the dynamic monitoring strategies demonstrated clear clinical superiority. This type of evidence, focused on patient-centred outcomes rather than purely technical parameters, provides a higher level of applicability for decision-making in obese patients undergoing laparoscopic surgery.

Future Research Directions

The growing incorporation of dynamic indices as tools to guide intraoperative fluid therapy has led to an emerging body of evidence in patients with morbid obesity. However, this line of research still faces significant methodological and clinical gaps that must be addressed in future research. One of the main limitations identified is the lack of standardisation in the cutoff values used to define fluid responsiveness. Most of the studies reviewed (Jain et al. 2010; Ali and Dorman 2019; Demirel et al. 2018) employed traditional thresholds such as SVV >10% or dPV >13%, which were established in normoweight populations. Nevertheless, patients with morbid obesity present significant pathophysiological alterations that can modify intrathoracic pressure transmission, thereby affecting the validity of these conventional thresholds. Additionally, surgery-related factors, such as the use of pneumoperitoneum in laparoscopy or prone positioning, may further amplify this variability (DeBarros et al. 2015; Flick et al. 2021). As a result, there is a clear need to define specific cutoff values for this population, ideally derived from well-designed physiological studies or meta-analyses focused on obesity. As Canesson notes, "Sometimes, even during ventilation with normal tidal volumes, interpreting PPV can be challenging when its value lies in the grey zone between 9% and 13%" (Michard et al. 2023).

Another relevant challenge is the discrepancy observed between invasive and noninvasive monitoring methods. Although noninvasive technologies (such as ClearSight® or PVi) represent an attractive option due to their lower risk and easier implementation, studies (Flick et al. 2021; DeBarros et al. 2015) have documented only moderate agreement compared to invasive monitoring, particularly at higher ranges of variation, where they may lead to inappropriate fluid overload decisions. This finding highlights the need for direct comparative studies between monitoring platforms, as well as cost-effectiveness and clinical applicability analyses, in order to determine the most suitable monitoring method based on surgical approach, patient BMI, and the haemodynamic goals of the procedure.

Regarding relevant clinical outcomes, most of the reviewed studies have focused on intermediate parameters such as fluid volume administered, serum lactate levels, or blood pressure. However, few studies (Urhan et al. 2024) have conducted comparative evaluations of renal function, tissue perfusion, and hospital length of stay, without identifying clinically significant differences between monitoring methods. This underscores the urgent need to advance toward randomised controlled trials assessing important outcomes, such as pulmonary complications, acute kidney injury, hospital length of stay, reoperation rates, or even postoperative mortality. Additionally, incorporating biomarkers of tissue perfusion and microcirculation may provide a more comprehensive understanding of the haemodynamic impact of decisions guided by dynamic indices.

Conclusion

The use of dynamic indices to predict fluid responsiveness has become a valuable tool for guiding fluid therapy. However,

in patients with obesity, the current body of evidence remains insufficient to define clinically validated reference values capable of impacting meaningful patient outcomes. This is largely due to the specific pathophysiological alterations in this population, such as intra-abdominal hypertension, positive pressure ventilation, and cardiovascular changes, which interfere with the accurate interpretation of these indices. Further studies are needed to establish population-specific cutoff values, with the goal of translating the benefits demonstrated by these technologies in general populations to more complex surgical scenarios, such as those involving patients with morbid obesity.

Conflict of Interest

None.

References

Ali A, Dorman Y, Abdullah T, Yasa C, Orhan-Sungur M, Akinci IO, Ergin-Ozcan P. Ability of mini-fluid challenge to predict fluid responsiveness in obese patients undergoing surgery in the prone position. Minerva Anestesiol. 2019;85(9):981-8.

Berger D, Werner Moller P, Bachmann KF. Cardiopulmonary interactions-which monitoring tools to use? Front Physiol. 2023;14:1234915.

Busebee B, Ghusn W, Cifuentes L, Acosta A. Obesity: A Review of Pathophysiology and Classification. Mayo Clin Proc. 2023;98(12):1842-57.

DeBarros M, Causey MW, Chesley P, Martin M. Reliability of Continuous Non-Invasive Assessment of Hemoglobin and Fluid Responsiveness: Impact of Obesity and Abdominal Insufflation Pressures. Obes Surg. 2015;25(7):1142-8.

Demirel İ, Bolat E, Altun AY, Özdemir M, Beştaş A. Efficacy of Goal-Directed Fluid Therapy via Pleth Variability Index During Laparoscopic Roux-en-Y Gastric Bypass Surgery in Morbidly Obese Patients. Obes Surg. 2018;28(2):358-63.

Elia J, Diwan M, Deshpande R, Brainard JC, Karamchandani K. Perioperative Fluid Management and Volume Assessment. Anesthesiol Clin. 2023;41(1):191-209.

Flick M, Mehr JM, Briesenick L, et al. Non-invasive measurement of pulse pressure variation using a finger-cuff method in obese patients having laparoscopic bariatric surgery. J Clin Monit Comput. 2021;35(6):1341-7.

Hamahata N, Pinsky MR. Heart-Lung Interactions. Semin Respir Crit Care Med. 2023;44(5):650-60.

Jain AK, Dutta A. Stroke volume variation as a guide to fluid administration in morbidly obese patients undergoing laparoscopic bariatric surgery. Obes Surg. 2010;20(6):709-15.

Michard F, Chemla D, Teboul JL. Meta-analysis of pulse pressure variation (PPV) and stroke volume variation (SVV) studies: a few rotten apples can spoil the whole barrel. Crit Care. 2023;27(1):482.

Monnet X, Teboul JL. Assessment of fluid responsiveness: recent advances. Curr Opin Crit Care. 2018;24(3):190-5.

Urhan G, Demirel İ, Deniz A, Aksu A, Altun AY, Bolat E, Beştaş A, Altuntaş G. Comparison of Dynamic Measures in Intraoperative Goal-Directed Fluid Therapy of Patients with Morbid Obesity Undergoing Laparoscopic Sleeve Gastrectomy. Obes Surg. 2024;34(5):1600-7.

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